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Anisotropy in strongly correlated electrons and its relationship with superconductivity

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Recently, symmetry-breaking phenomena have been successively found in various superconductors; electronic nematic order breaking the rotational symmetry [1] and charge density wave breaking the translational symmetry [2] were experimentally discovered along with superconductivity (SC). Thus, it is urgent to clarify the relationship between these novel symmetry breaking phenomena and SC because they may provide important insights into the relationship between SC and the enigmatic pseudogap state. Pomeranchuk instability, a spontaneous breaking of four-fold rotational symmetry of the Fermi surface without lattice distortion, is a noteworthy candidate for the nematicity observed in cuprate superconductors [3].

In this presentation, we check whether an anisotropy spontaneously appears or not in strongly correlated electrons that have a complex phase diagram of SC and antiferromagnetism (AF). To this end, we use a variational Monte Carlo method (VMC) for the square-lattice Hubbard model with diagonal transfer t' and large U, and consider the relationship between the anisotropy and SC when the model parameters varied.

We introduce the following features in trial wave functions: (1) Band renormalization effect owing to electron correlation is introduced by adjusting the parameters of hopping integrals, some of which have degree of freedom of anisotropy in x and y directions. (2) As multi-body correlation factors, a doublon-holon binding factor and an on-site Gutzwiller factor are used to capture the essence of strong correlation.

First, we calculate the properties of pure SC, pure AF, and normal states individually by VMC method and consider what is the most important factor in Pomeranchuk instability by comparing the magnitude of x-y anisotropy. Next, we adopt a mixed state of AF and SC orders as a trial wave function, by which we can treat the orders continuously from their coexistence to the mutual exclusivity. With this wave function, we will clarify the relationship between anisotropy and SC or AF order in the strongly correlated regime.

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